eRD108 R&D program: Development of Cylindrical MPGDs

- **Two very distinct motivations for cylindrical MPGD R&D for EIC detector:**

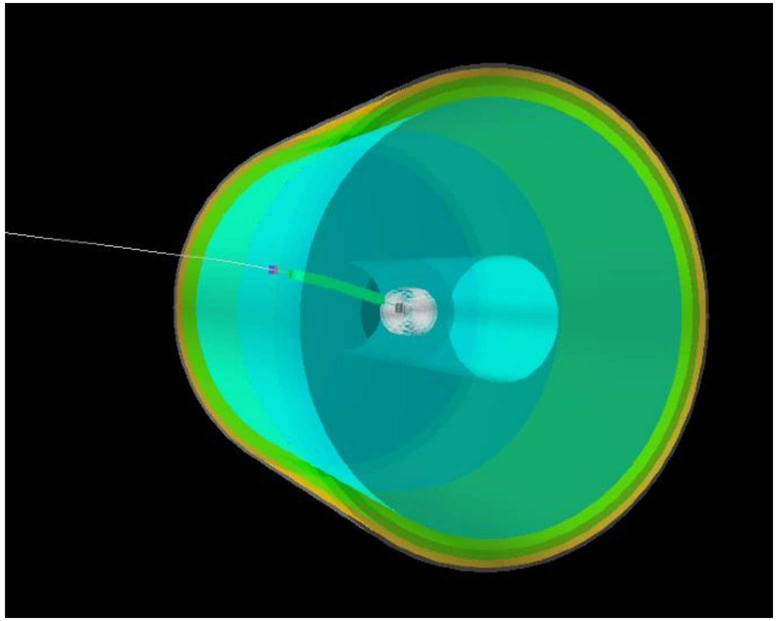
  1. a single cylindrical µRWELL layer directly in front of (and behind) the DIRC subdetector
     - Provide precise directional information to help seed the DIRC Cherenkov ring reconstruction
     - Tracking layer needed in all 3 EIC detector concepts **(ECCE, CORE & ATHENA-all-Si)**
     - Less stringent requirement for low mass detector (thickness > 0.5% r.l. is OK)
  2. several cylindrical Micromegas (MM) detector layers to create a central barrel tracker
     - This is a MPGD of choice for the **ATHENA-Hybrid Tracking** subdetector in the barrel region
     - Development of low mass detector (< 0.5% r.l.) is critical.

- **Different applications & different R&D focus**
  - We want to emphasize that our R&D program targets two different applications for these two subdetectors
  - The R&D focus mean that the two technologies are not to be considered interchangeable
  - Both R&D projects share common goal for development / optimization of 2D readout patterns for MPGDs.

Development of Cylindrical µRWELL Tracker for the DIRC

- Motivation:
  - Impact position and directional information needed to seed the DIRC ring reconstruction.
    - Cylindrical µRWELL is the technology of choice as tracking layer in front of the DIRC
    - Aim at 1 mrad resolution at DIRC entrance point combined with central tracker
  - Tracking layer required for all 3 current EIC detectors (**ECCE, ATHENA all-Si & CORE**)
- Objectives:
  - Demonstrate with a small prototype that cylindrical µRWELL can be built and operated
- R&D Plans for FY2022 & FY2023:
  - Design and fabrication of the mechanics of the cylindrical µRWELL prototype **(FY2022)**
  - Design and procurement of the µRWELL amplification & readout composite foil **(FY2022)**
  - Acquisition of small size VMM3a-SRS readout electronic **(FY2022)**
  - Characterization of the prototype with X-Ray at BNL and in beam at FNAL **(2023)**
- Institutions involved in Cylindrical µRWELL for DIRC:
  - **FIT:** Mechanical structure of the cylindrical µRWELL
  - **UVa:** µRWELL amplification & capacitive-sharing 2D strip readout
  - **BNL:** µRWELL amplification & 2D zigzag readout structure
  - **TU:** VMM3a-SRS readout for cylindrical µRWELL prototype

Fast tracking layer for DIRC reco.



- Budget Request for Cylindrical µRWELL

This a combined funding request from BNL, FIT, TU & UVa for Cylindrical µRWELL

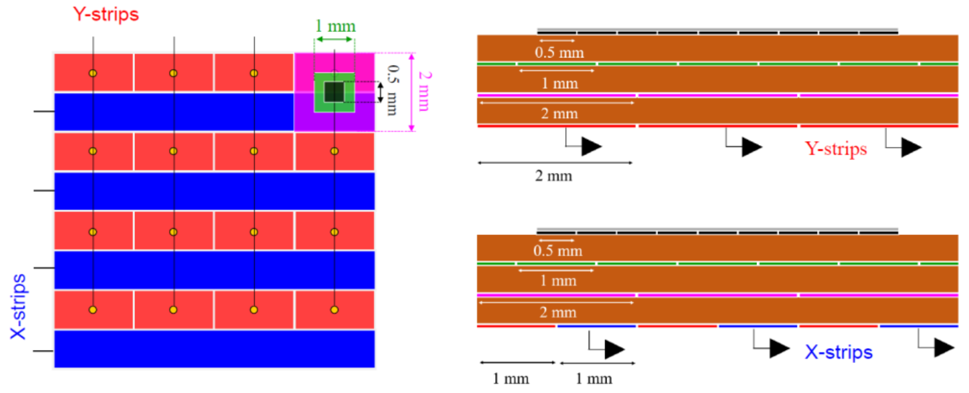
- FY2022: **$157,305**
- FY2023: **$180,425**

Cylindrical µRWELL: R&D @ UVa

❖ Develop the composite µRWELL readout foil:

- ❖ Design of composite µRWELL readout foil collaboration with FIT, TU & BNL.
- ❖ Combines µRWELL amplification device with capacitive-sharing 2D strip readout structure (1mm - 2 mm pitch) into single µRWELL readout foil.
- ❖ Explore "diagonal, 90-degree, **U-V**" strip or CLAS12 MVT **C-Z** strip configuration for the cylindrical geometry.
- ❖ Procure the parts from CERN and perform initial quality control test before assembly into cylindrical mechanical at FIT
- ❖ Participate in the joint beam test of the prototype at BNL & FNAL in 2023

Concept of capacitive-sharing strip readout



❖ Person-power required and available

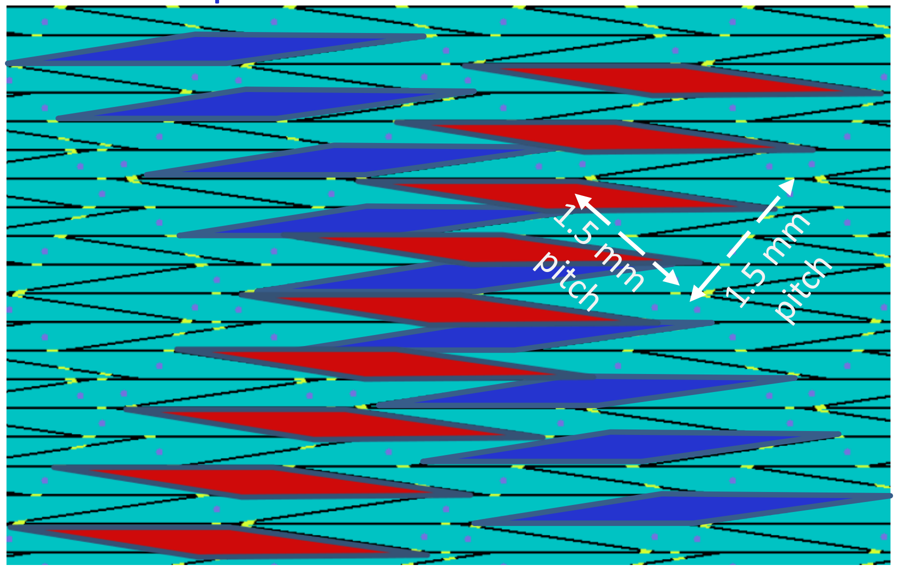
- ❖ FY2022: UVa Research Scientist (K. Gnanvo, unfunded), UVa graduate student (TBD, 25% FTE)
- ❖ FY2023: UVa Research Scientist (K. Gnanvo, unfunded), UVa graduate student (TBD, 25% FTE)

UVa Budget Table

UVa BUDGET DRAFT FY22	Cyl. uRWELL	Forward Tracker
	$15,000	$0
Travel	$3,000	$2,000
Materials	$14,000	$10,000
overhad (26%)	$3,640	$2,600
TOTAL	$35,640	$12,600
UVa BUDGET DRAFT FY23	Cyl. uRWELL	Forward Tracker
Graduate students	$15,000	$15,000
Travel	$5,000	$5,000
Materials	$3,000	$3,000
overhad (26%)	$760	$760
TOTAL	$23,760	$23,760

Cylindrical µRWELL: R&D @ BNL

- Develop the composite µRWELL readout foil:
  - Design of the µRWELL composite readout flex PCB in collaboration with CERN, FIT, TU and UVa
  - Develop large scale charge-sharing 2D zigzag strip (pad) layout with 1.5 - 2.0 mm pitch for µRWELL readout foil
  - Perform X-ray stand characterization of the devices at BNL
  - Participate in the joint beam test at FNAL in summer 2023
- Small scale chamber characterized with X-ray gun:
  - A single chemically etched kapton foil (CERN); quadruple GEM
  - Spatial resolution for 1.5 mm pitch: ~70 µm in U&V **at once**
  - Differential non-linearity <50 µm
- Person-power available part time
  - BNL NPP Staff: B. Azmoun, A.Kiselev, M. Purschke, C. Woody



BNL eRD108 Budget table

BNL BUDGET DRAFT	FY22	FY23
Materials (uRwell board)	$5,000	
Technical support	$5,000	$4,000
Travel (beam test in FY23)	$2,000	$7,000
TOTAL CORE COSTS	$12,000	$11,000

Cylindrical µRWELL: R&D @ FIT

FLORIDA TECH

❖ Design and fabrication of the mechanical support structure

- ❖ Design of mechanical structure in collaboration with BNL, TU & UVa.
- ❖ Investigate carbon fiber prepreg (CF) material for rigid but light support structure
- ❖ µRWELL readout foil mounted in the outer side of one CF cylinder
- ❖ Drift cathode foil mounted in the inner side of a second concentric CF cylinder
  - ❖ Minimization of drift cathode support material
- ❖ Fabrication of the support structure and assembly of µRWELL readout foil (2022)
- ❖ Participate in the joint beam test campaign of the prototype at BNL & FNAL (2023)

❖ Person-power required and available

- ❖ FY2022: Faculty (M. Hohlmann, unfunded), FIT graduate student (Pietro Iapozzuto, 75% FTE).
- ❖ FY2023: Faculty (M. Hohlmann, unfunded), FIT graduate student (Pietro Iapozzuto, 75% FTE).

FIT eRD108 Budget table

FIT BUDGET DRAFT FY22	Request	Forward	uRWELL	v4 9/9/21
Graduate students	*$32,000*	$8,000	$24,000	Total
	$10,000	$0	$10,000	Pietro S22
	$10,000	$5,000	$5,000	Merrick S22
	$6,000	$0	$6,000	Pietro Sum 22
	$6,000	$3,000	$3,000	Merrick Sum 22
Undergraduate students (1)	$3,000	$0	$3,000	Sum 22
Travel	$2,000	$0	$2,000	
Materials	$8,500	$500	$8,000	
IDC base (Stud. & travel & mat.)	$45,500	$8,500	$37,000	
IDC	$20,415.85	$3,813.95	$16,601.90	
TOTAL	$65,916	$12,314	$53,602	

FIT BUDGET DRAFT FY23	Request	Forward	uRWELL	
Graduate students	*$52,000*	$26,000	$26,000	Total
	$10,000	$0	$10,000	Pietro F22
	$10,000	$0	$10,000	Pietro S23
	$10,000	$10,000	$0	Merrick F22
	$10,000	$10,000	$0	Merrick S23
	$6,000	$0	$6,000	Pietro Sum 23
	$6,000	$6,000	$0	Merrick Sum 23
Undergraduate students (1)	$0	$0	$0	Sum 23
Travel	$9,000	$0	$9,000	
Materials	$2,500	$500	$2,000	
IDC base (Stud. & travel & mat.)	$63,500	$26,500	$37,000	
IDC	$28,492.45	$11,890.55	$16,601.90	
TOTAL	$91,992	$38,391	$53,602	

Brookhaven National Laboratory

Cylindrical µRWELL: R&D @ TU

TEMPLE UNIVERSITY

- Design and commissioning of small scale VMM-SRS electronics and DAQ system
  - Move beyond APV ASIC (no longer produced) to VMM ASIC which has attractive characteristics for µRWELL cylindrical tracker
  - Collaborate with BNL, FIT & UVa as well as RD51 @ CERN to become trained and gain expertise in VMM-SRS
  - Use VMM-SRS electronics already in hand (via UVa eRD6 purchase) to commission a small-scale system (2022)
  - Procure and commission large scale VMM-SRS DAQ system to readout cylindrical µRWELL prototype (2023)
  - Participate in the joint beam test campaign of the prototype at BNL & FNAL (2023)

TU eRD108 Budget table

TU BUDGET DRAFT (FY22)	Percentage	Request
Postdoc (TBD)	50.00%	$28,184
Fringe Benifit		$7,187
Total Personal		$35,371
Travel		$0
Materials		$0
Equipment		$0
Total (Personal. & travel & mat.)		$35,371
Overhead		$20,692
TOTAL		$56,063
TU BUDGET DRAFT (FY23)	Percentage	Request
Postdoc	50.00%	$28,184
Fringe Benifit		$7,187
Total Personal		$35,371
Travel		$6,000
Materials		$0
Equipment		$30,000
Total (Personal. & travel & mat.)		$41,371
Overhead		$20,692
TOTAL		$92,063

- Person-power required and available
  - FY2022: TU Research Scientist (M. Posik, unfunded), TU postdoc (50% FTE).
  - FY2023: TU Research Scientist (M. Posik, unfunded), TU postdoc (50% FTE).

R&D on cylindrical Micromegas tracker

Motivation

- Build a full (no acceptance gaps) light-weight modular Micromegas barrel tracker to complement the silicon vertex detector
- Take the existing tech from CLAS12 and uprgrade it to be:
  - **Simpler construction** (i.e. one PCB to rule them all)
  - **2D readout** (resistive strip stack or 2D zigzag)
  - Even **lighter** (from ~0.4%X0 to as low as 0.07%X0)

Objectives

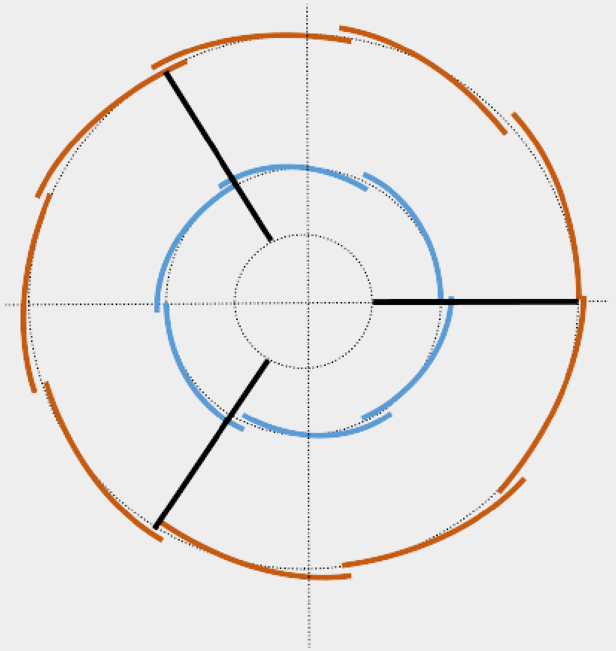
- FY22:
  - Optimization of the 2D readout to reach resolutions of ~150um with the fewest possible number of channels on small prototypes
  - CAD design of the full-scale prototype
  - Build and test small demonstrators for ultra-low-X0 solutions
- FY23:
  - Build a full scale prototype of a Micromegas tile (50x70cm^2) with the chosen 2D readout and test it

Involved institutions

- CEA-Saclay: 2D readout design, bulking and building, cosmics and beam testing
- BNL: 2D zigzag readout design, X-Ray and beam testing

Budget request

- FY22: $36,000 (Saclay + BNL)
- FY23: $43,500 (Saclay + BNL)



Micromegas tracker configuration

Current estimates:

- 2 layer at r ~ 50 cm with 2x9 tiles
- 2 layer at r ~ 80 cm with 4x12 tiles

Total ~ 124 tiles = ~40 m²
RO: pitch 1 mm = ~100,000 channels

2D Multi stack @ Saclay

Make resistive Amplification Kapton (AK)
- Diff. resistive value, strip shape
- Strait & Zigzag strip, Plain surface
- Diff. “grounding” with wasp waist

In house serigraphy ~ 9 pattern /screen
In house bulk with 4 pattern / mesh

\+

Use of different Readout Kapton (RK)
- Diff. strip pitch
- Strait strip, Zigzag strip, pixel,…
- Max 128 channel
- Purchase Kapton 4 patterns / foil
- Flexibility to integrate third party RK

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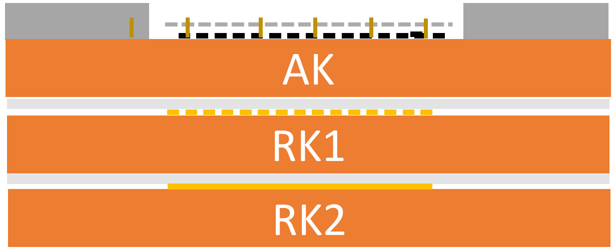
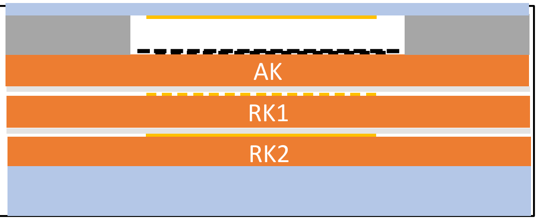


Assembly of different AK + RK1 + RK2
- One AK and two RK at 90°
- Diff. combination of AK & RK stack
- Low capacitance stack search
- In house press with frame
- In house full 3D mechanics

Detector RD4
Active area on 10x10 cm²
Kapton of 20x20 cm²
128 channel, Floating mesh

Characterization in FY22
- ^{55}Fe & Cosmic bench in Saclay with DREAM FEE
- Shipment to BNL for test with X-Ray gun
- Beam test at FNAL



Saclay BUDGET DRAFT FY22 – 2D readout	**Request**
Materials: **Readout Kapton, bulk and mechanics**	$12 000
Travel: **Beam test at FNAL**	$4 000
Total	**$16 000**

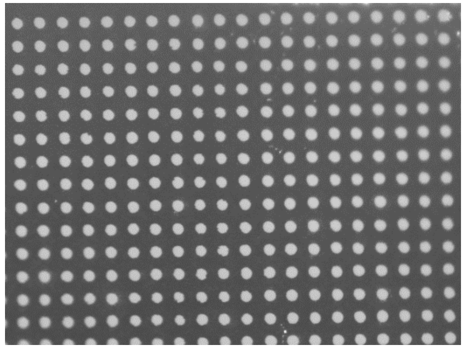
Saclay BUDGET DRAFT FY23	**Request**
Materials: **Construction of a full scale prototype**	$32 000
Travel: **Beam test**	$4 000
Total	**$36 000**

R&D on ultra low X0 (remove FR4, Stainless Steel, Cu)

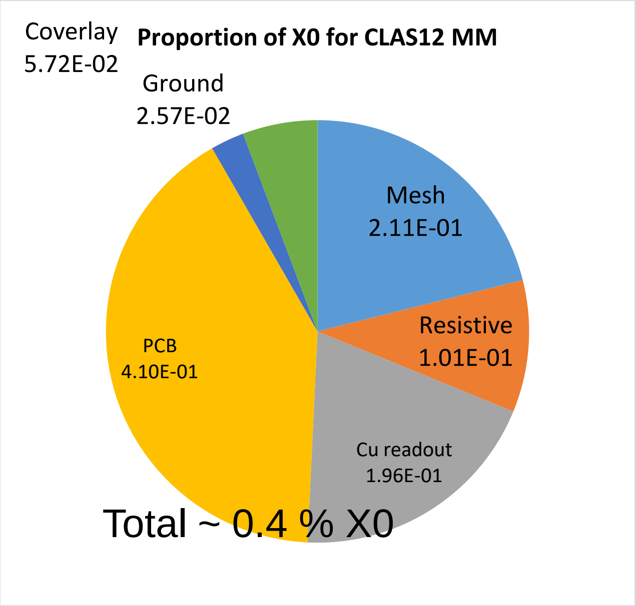
Goal: **reach as low as 0.07% of X0**. Technology of interest not only for barrel applications

Ongoing
- Bulk on resistive kapton layer (no FR4): AK (Amplification Kapton)
  - Already tested on 25x25 cm²
  - large seize (50x50 cm²): Kapton with resistive layer
  - Kapton bulked on mesh, then glued on frame
  - Possibility to press in house Kapton readout under

- **FY22**
  - **Aluminum thin mesh (no Stainless Steel)**
    - Lasea (www.lasea.eu/en/) laser machine manufacturer with R&D lab.
    - 5 k€ quotation for drilling of sample (Al 5 to 20 µm, Cu, …) in FY 21
    - **Small 10x10 active area mesh for bulk in FY22**
    - Explore machine for large surface FY23
- FY23
  - Aluminum metalized strip on Kapton/mylar for readout (No Cu)
    - Research for company
    - Test of material on KA with R&D on Al-Cu signal connection.



10 µm Al Laser mesh



Saclay BUDGET DRAFT FY22 – Ultra Low X0	Request
Materials: **Purchase of thin Al mesh**	$5 000
Total	**$5 000**
Saclay BUDGET DRAFT FY23 – Ultra Low X0	**Request**
Materials: **Mesh and metalised strips**	$10 000
Total	**$10 000**

2D zigzag for μMegas @ BNL

Brookhaven National Laboratory

FY22 activities

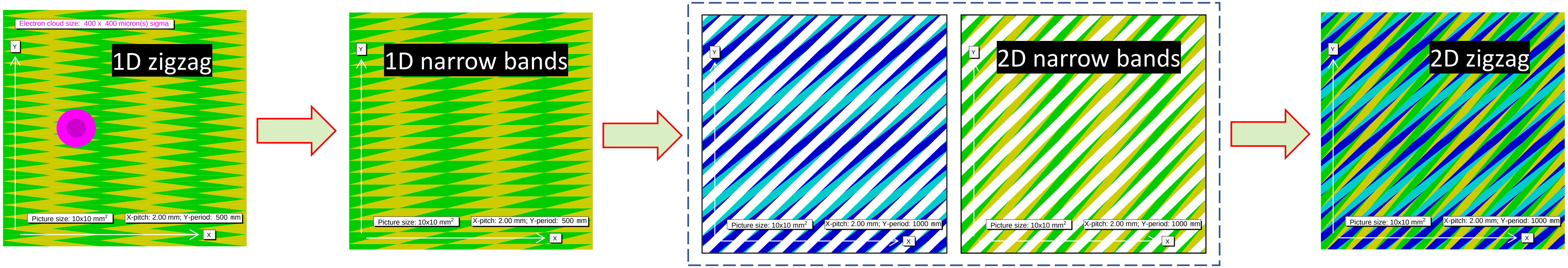
- Design a set of kapton-based 2D zigzag charge sharing readout boards matching Saclay prototype mechanics and interconnect
- Perform prototype characterization with X-ray gun at BNL
- Participate in a joint beam test at FNAL in spring 2022

BNL eRD108 Budget table

BNL BUDGET DRAFT	FY22	FY23
Materials (uMegas boards)	$6,000	
Technical support	$5,000	$4,000
Travel (beam test)	$7,000	
TOTAL CORE COSTS	$18,000	$4,000

This is NOT a duplicate of the μRWELL budget line but rather a half of the overall request

Low material budget, low channel count, high 2D spatial resolution



The technique must be scalable (kapton chemical etching) and is equally applicable to GEM / μRWELL / μMegas

Need further R&D for EIC Forward Tracker

- Motivation:
  - eRD6 was generic R&D for development of low mass GEM (< 0.5% r.l.)
    - R&D program was completed & successful with 2 large GEM prototypes built and tested in beam at FNAL (Florida Tech and UVa)
    - Focus on low mass in active area **but not** on the detector support structures.
  - Simulation ATHENA-Hybrid detector shows the need to minimize the planar MPGD detector frames in end cap regions
- Objectives & target of the R&D:
  - Investigate materials to minimize thickness and width while maintaining robustness for GEM support frame
  - Develop planar µRWELL detector as alternative to GEMs
  - Build and test prototype in beam test at FNAL
- Institutions involved in planar MPGDs for EIC Forward Tracker
  - Florida Tech, TU, UVa

- Budget Request for Forward Tracker

This a combined funding request from FIT, UVa

- FY2022: **$24,914**
- FY2023: **$62,151**

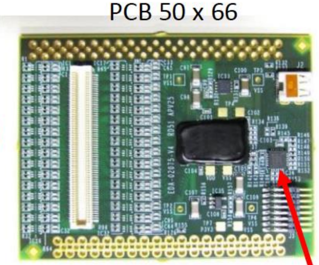
eRD108 Budget Table

Institution	FY22 request	FY23 request
BNL	$30,000	$15,000
FIT	$53,602	$53,602
UVa	$50,240	$47,520
Saclay	$21,000	$36,000
TU	$56,063	$92,063
TOTAL	$210,905	$244,185

Backup

SRS from APV to VMM3a

PCB 50 x 66



APV 2009-2019

Pansonic connector

PLL chip

- **Analogue**
- 128 channels with single chip
- AC coupled 100pF
- Master or Slave
- Embargo list countries
- 1/2 W per hybrid
- Cooling negligible
- No zero suppression
- Ext. Trigger required
- Max trigger rate **O(5kHz / hybrid**)
- timing resolution O(~5 ns)
- No clustering logic
- fixed preamp gain 65mV/fC
- fixed peaking time 50 ns in peak mode
- Noise ca 2000 e- @ C_{det}~ 50 pF
  (246 e + 36e-/pF in peak mode)
- max. detector Capacity C_{det} ~ 50 pF
- fixed CSA gain -> dyn. range 50 fC
- linear up 4 MIPs

PCB 50 x 85

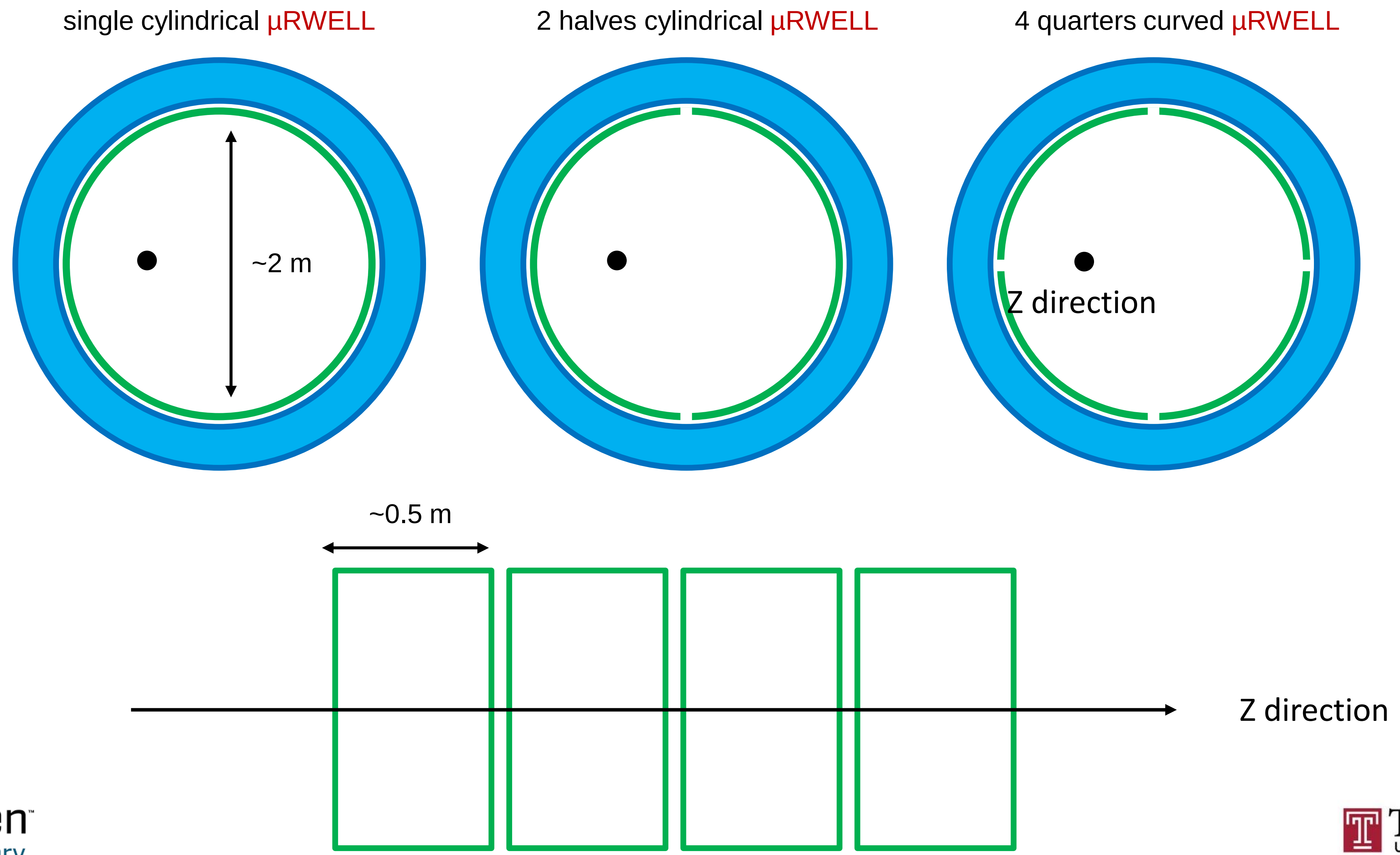
VMM 2019 +

HRS connector

FPGA, Flash and uADCs

- **Digital**
- 128 channels with 2 VMM chips
- AC coupled 470 pF @ 1M with TVS spark protection
- Master = Slave
- No embargo, BNL licence may apply to non-RD51 teams
- 3.5W per hybrid, 2 supply voltages P2~ 2V(3W),P1 ~3V(0.5W)
- Cooling important (convection cooler = standard, water pipes optional)
- Self-triggered with Zero suppression
- ART flag + 7 bit 1st hit address withing BCID period
- Trigger rates **O(1 MHz /channel)**
- timing resolution O(< 1ns)
- Neighbor detection below threshold for higher space resolution
- 8 different preamp gains 0.5-16mV/fC
- 4 different peaking times 25- 200ns
- channel pulser programmable via 10 bit DAC up 1V
- analogue monitoring: selected channel sheper peak and time
  temperature, baselines etc, SRS hybrid readout via 12bit uADC , I2C
- Noise 500e- intrinsic, 1300 e- @ C_{det} ~ 50pF
- max. detector capacity C_{det}~ 2nF in high capacity mode
- CSA linear dynamic range up 2 pC @ gain 0.5mV/fC

Cylindrical µRWELL: full size tracking layer



SBS U-V GEM tracker @ JLab: 2D readout with U-V strips

U-V Strip readout design:

⇨ U and V pitch of **400 μm**, Vertical pitch: **462 μm**

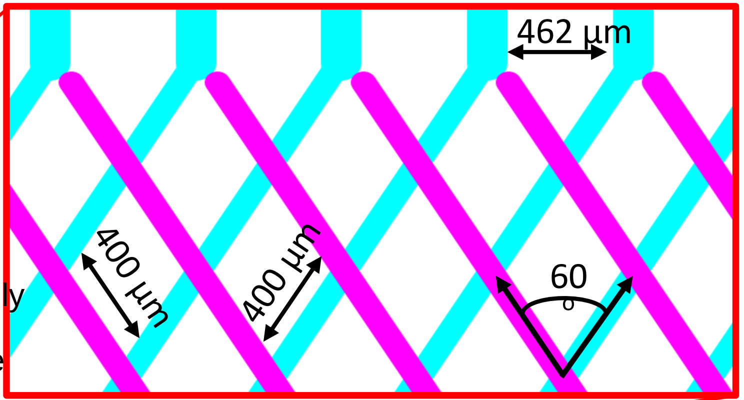
⇨ top (U-) strip: **80: μm**

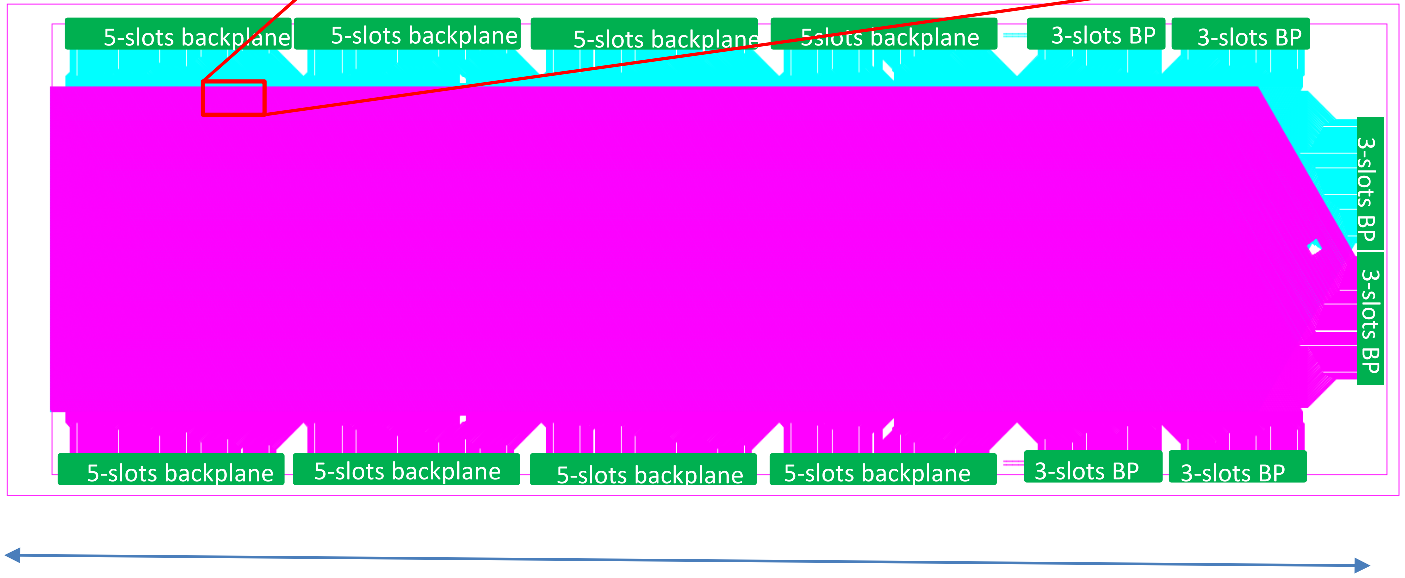
⇨ bottom strips: **350 μm**

⇨ About 7k e- channels per layer

❖ Will rearrange connectors on the detector to have 4-slots only

❖ Avoid HDMI 5th data lines & reduced number of HDMI cable





150 mm